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# (54) Manufacture of aircraft wings.

(57) The wing has components comprising at least a front spar (26) a rear spar (29), wing ribs and stiffened upper and lower aerodynamic profile-defining skin panels (13) (20) (21) (22) (23) and the method includes the steps of forming a first sub-assembly (11) including the front spar (26), front wing rib portions (30) and front upper and lower skin panels (23) (22), forming a second sub-assembly (12) including the rear spar (29), rear wing rib portions (31) and rear upper and lower skin panels (20) (21) and mating together front and rear wing rib portions (30) (31) and upper and lower skin panels (13) (20) (21) (22) (23) respectively of the first and second sub-assemblies (11) (12) to form the wing (48). The lower mid skin panel (13) goes on last so that there is ready access to the wing interior prior to this last step.

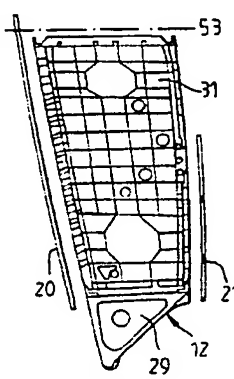


Fig.7a

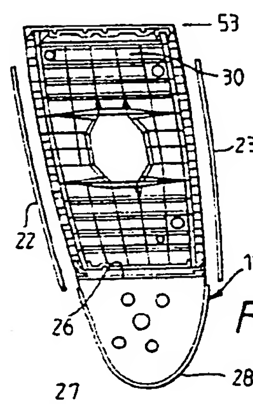


Fig.7b

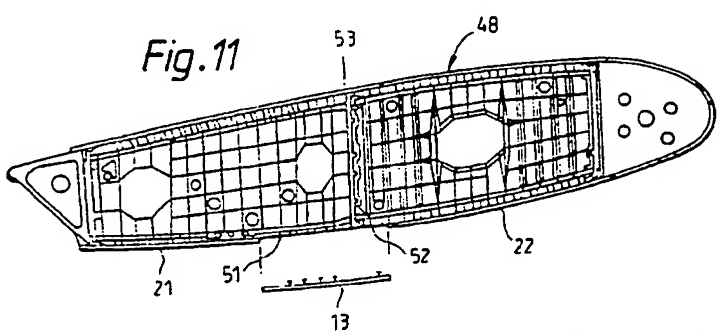


Fig.11

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1990.

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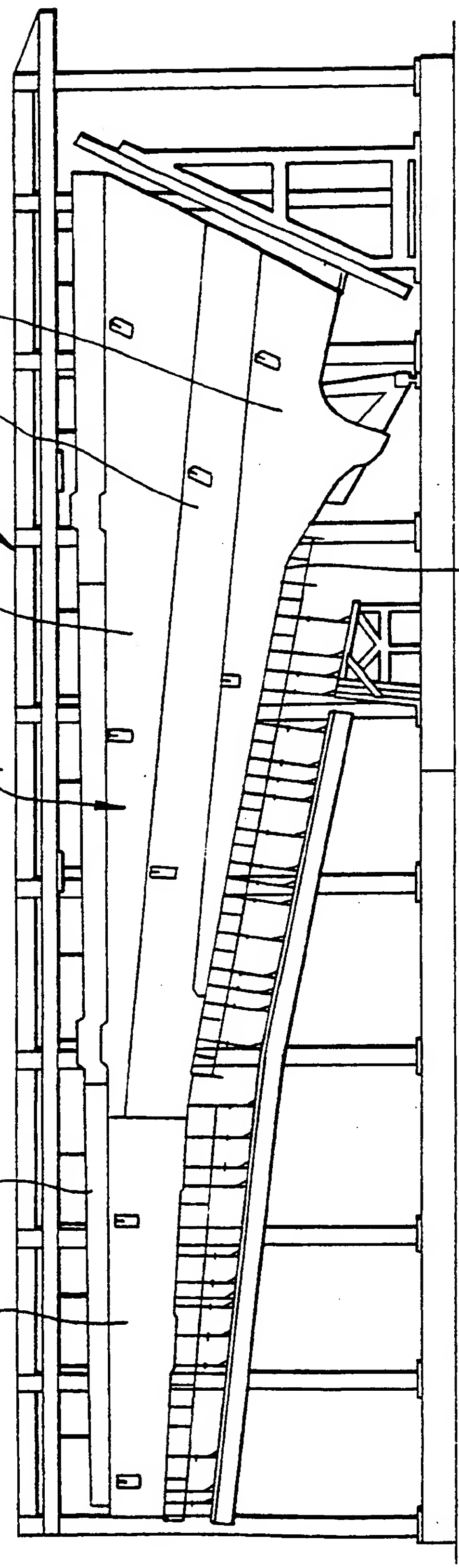



Fig.1 (Prior Art)

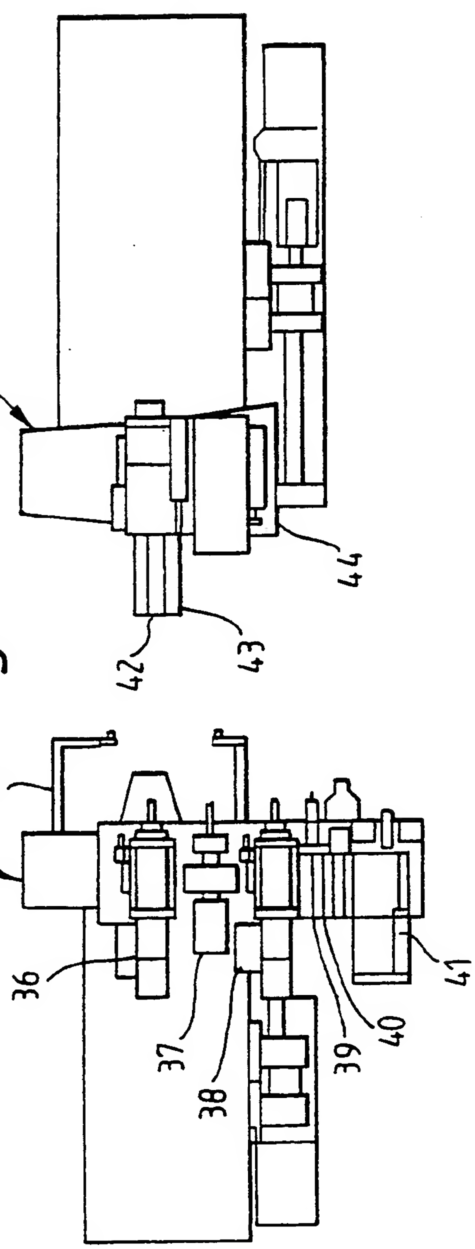



Fig.13

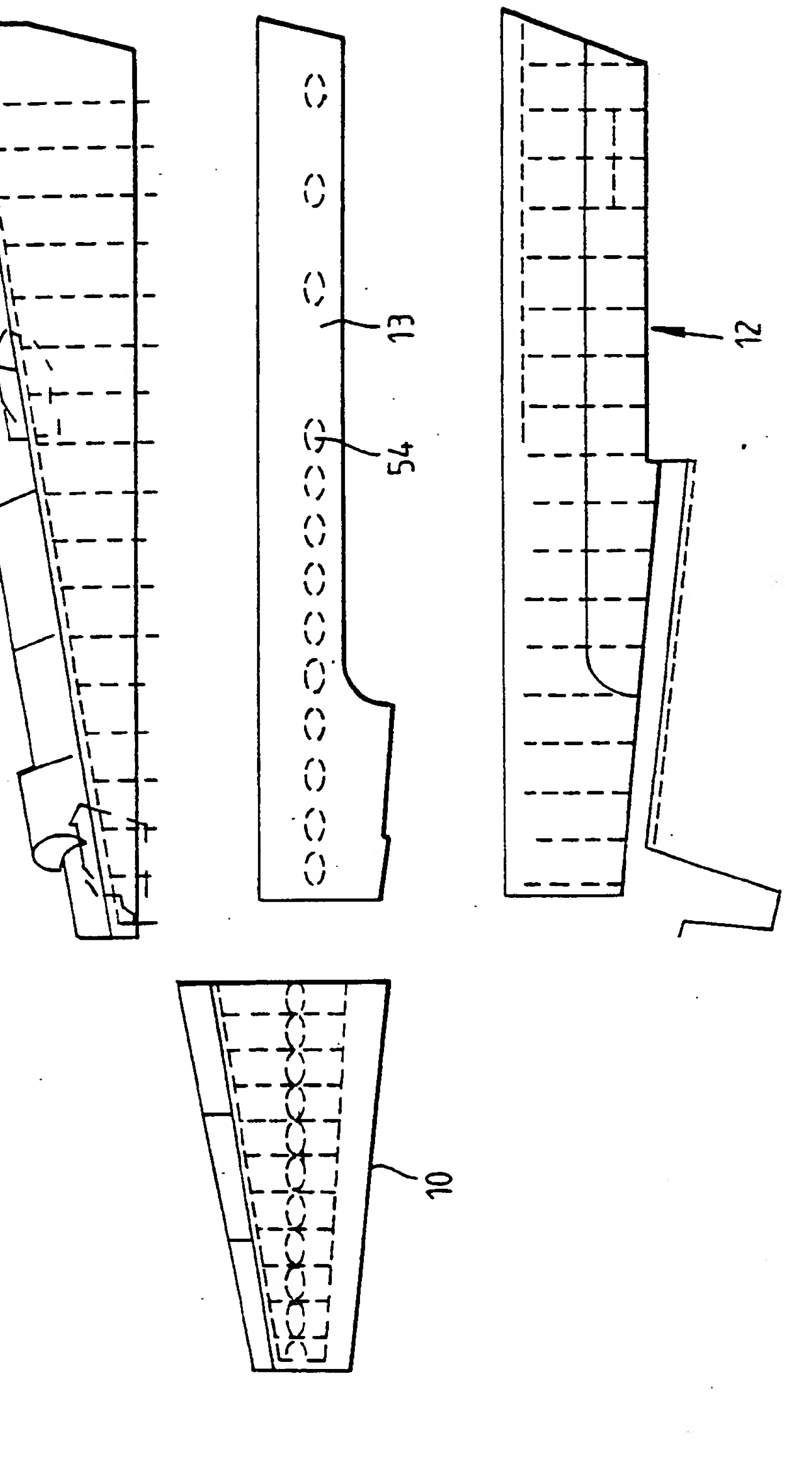



Fig. 2

Fig. 3

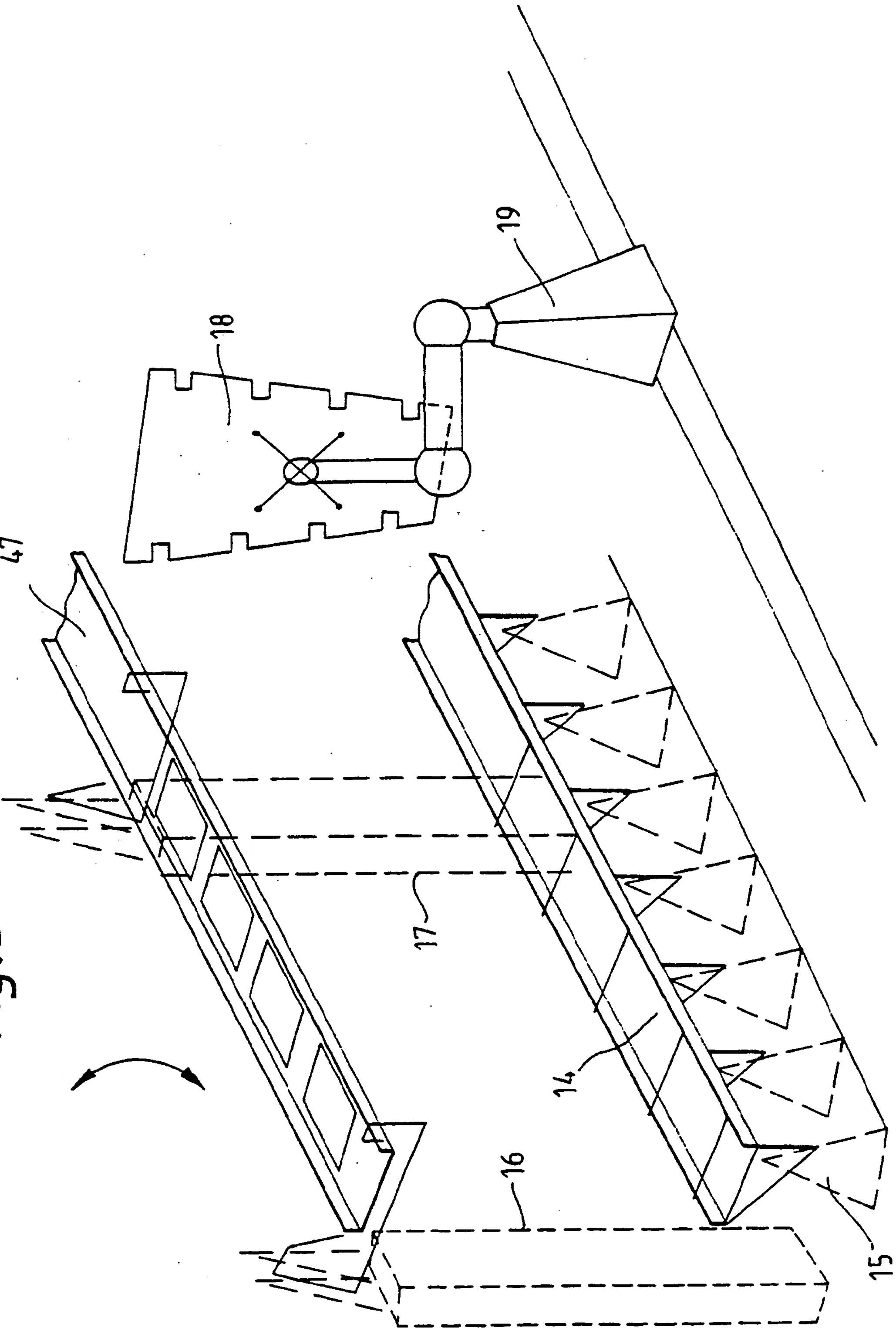


Fig. 4

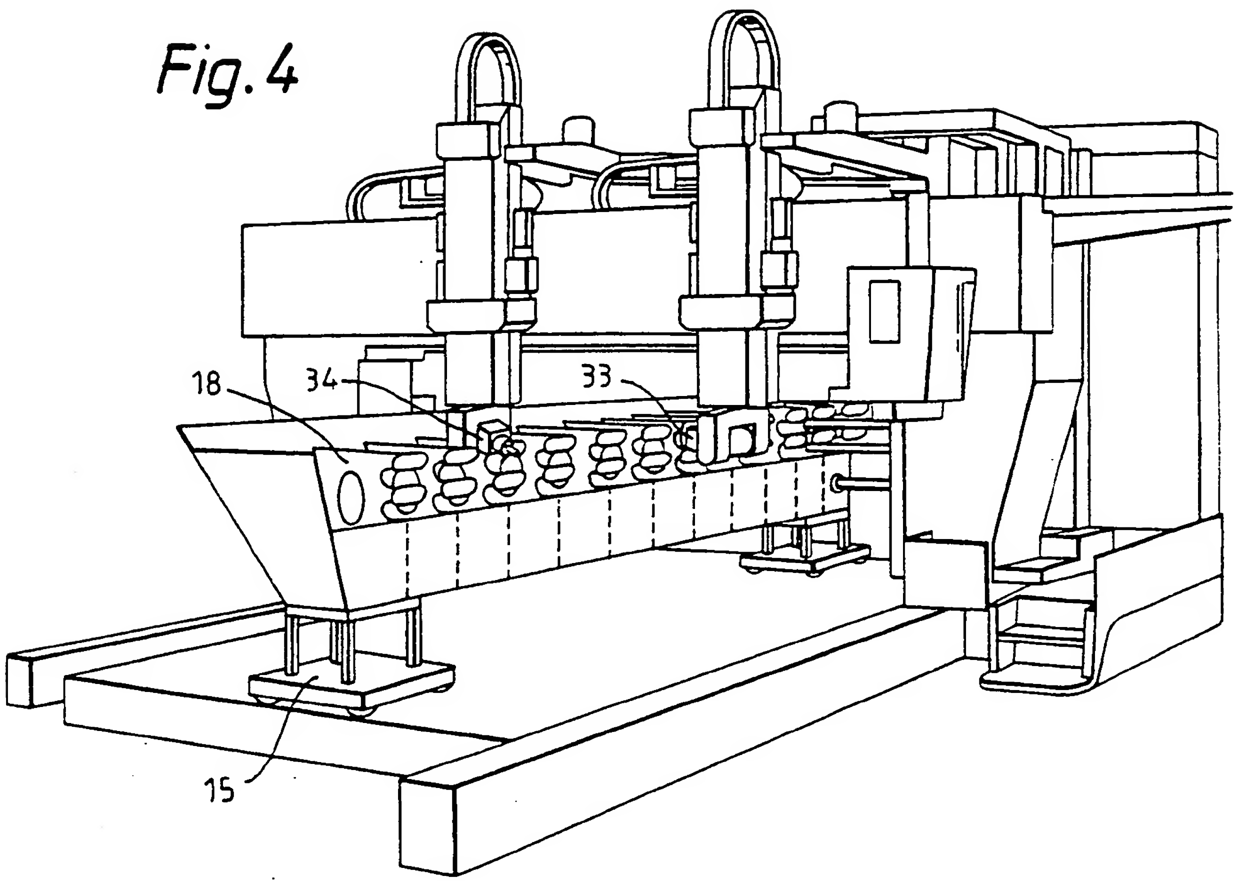
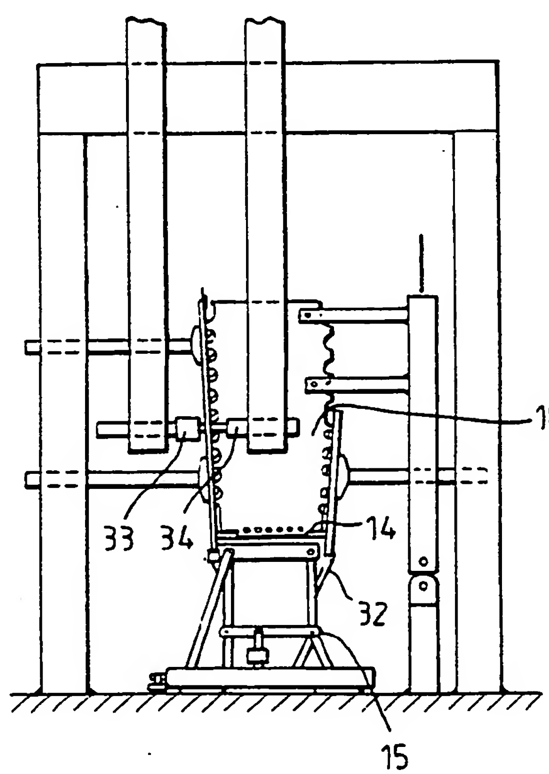



Fig. 5



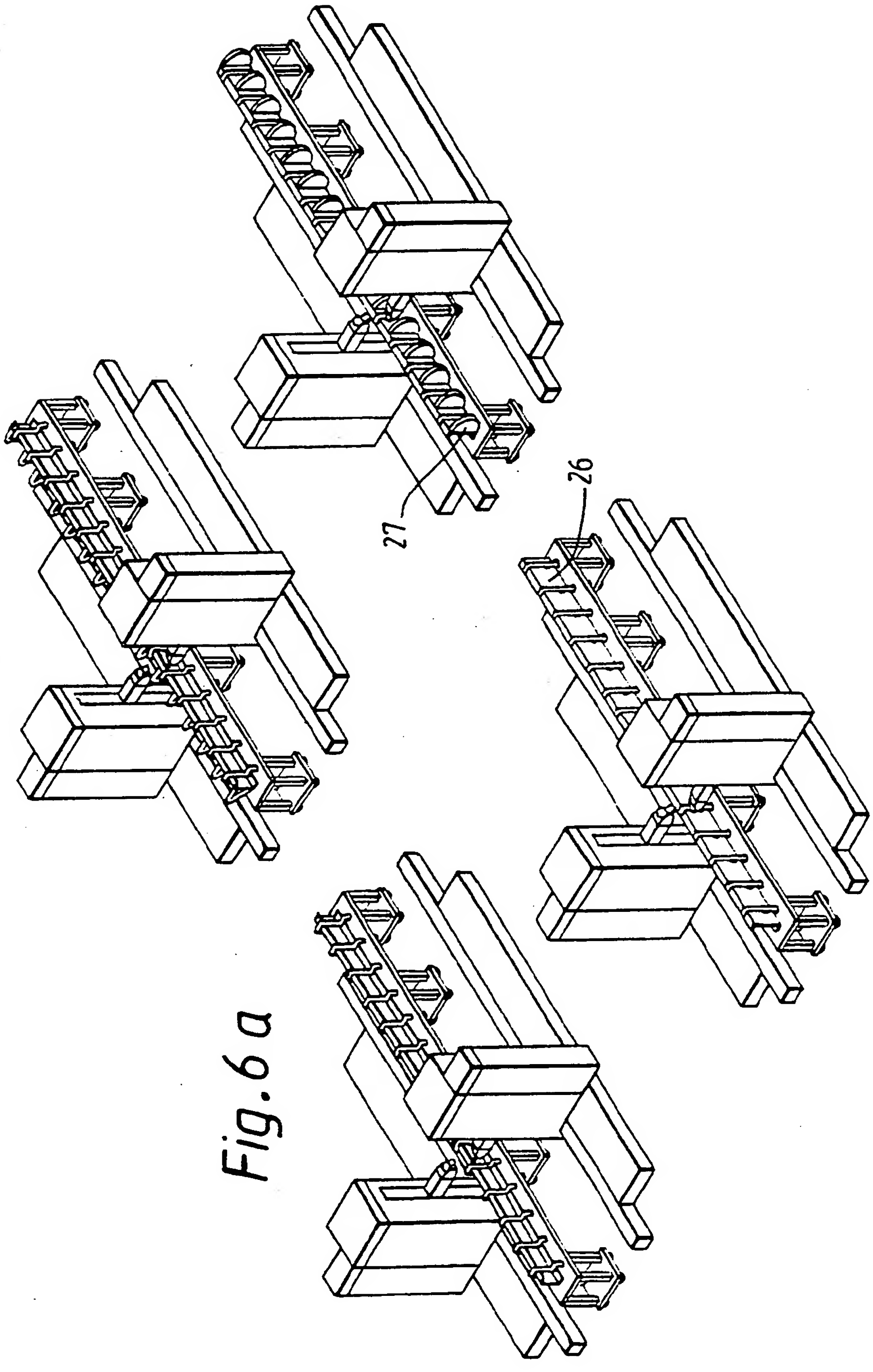



Fig.6

Fig.6a

Fig.6b

Fig.6 (cont.)

Fig.6c

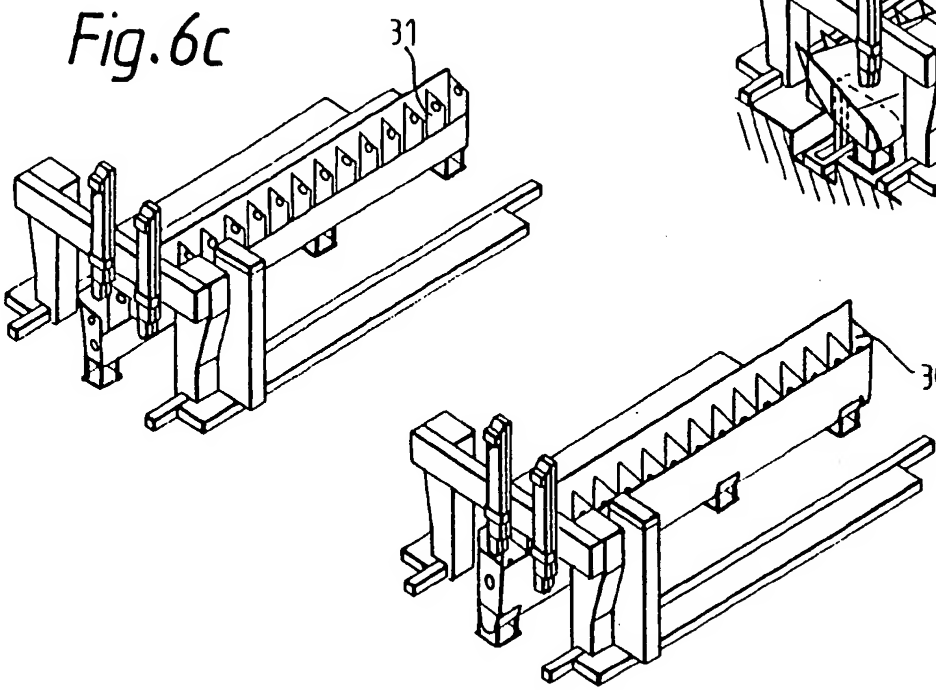
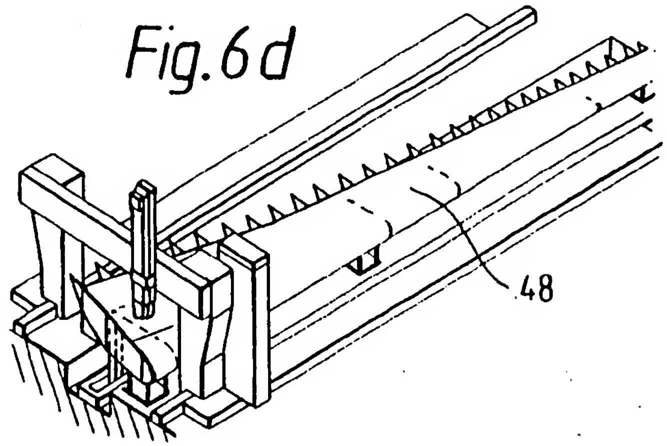



Fig.6d



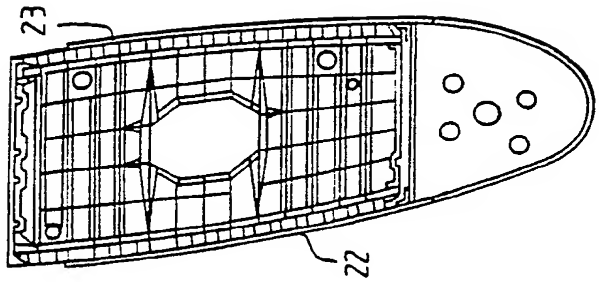



Fig.8b

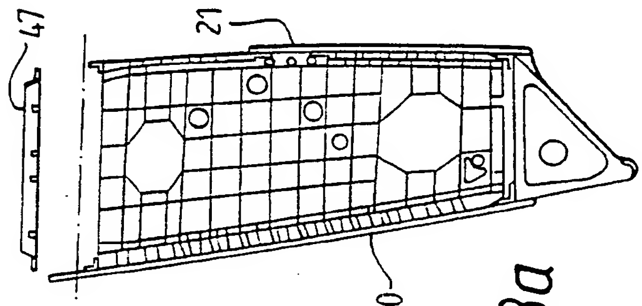



Fig.8a

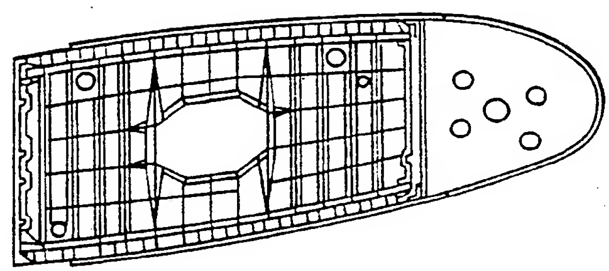


Fig.9b

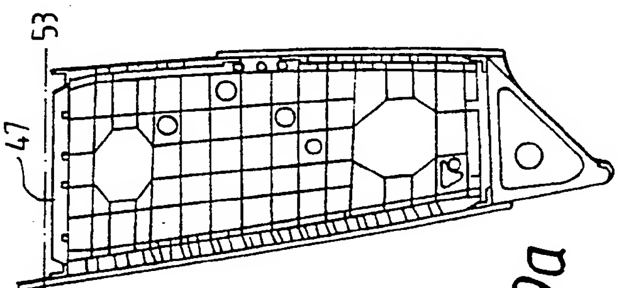



Fig.9a

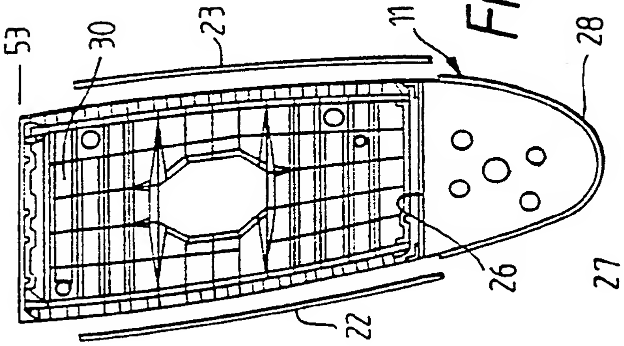



Fig.7b

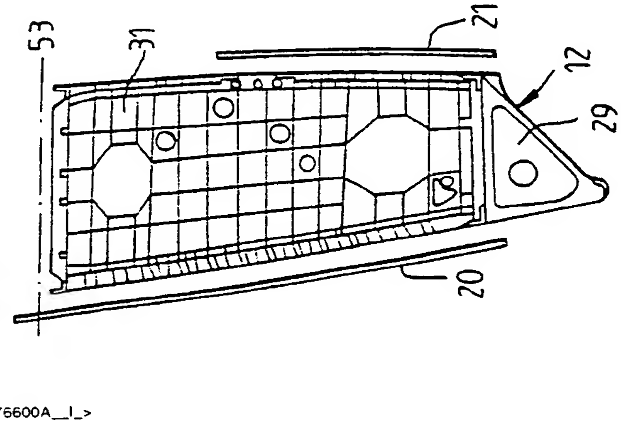



Fig.7a

Fig. 10

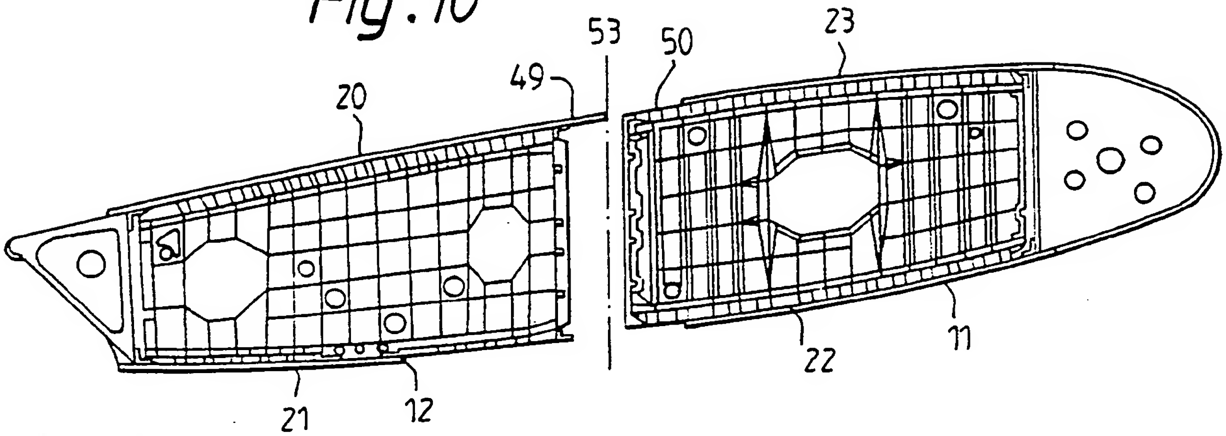



Fig. 11

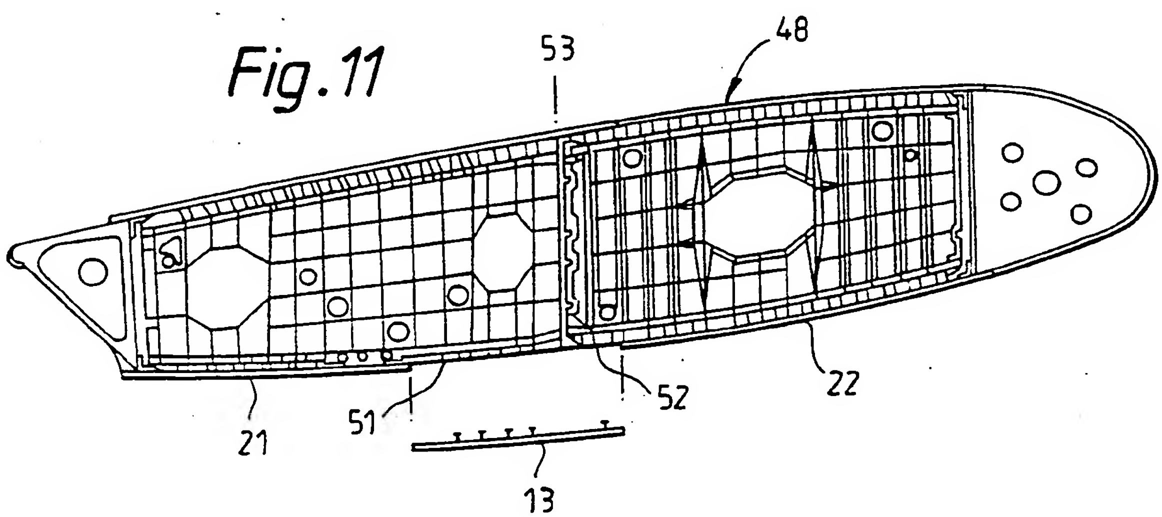
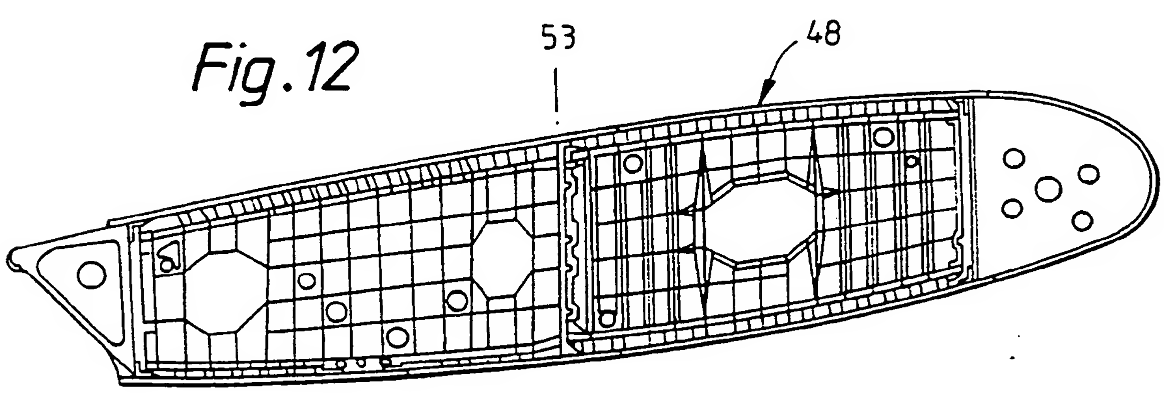



Fig. 12



# MANUFACTURE OF AIRCRAFT WINGS

This invention relates to the manufacture of aircraft wings and more particularly to the manufacture of wing torque boxes by fabrication techniques.

Aircraft wing torque boxes of the type comprising a front spanwise extending spar, a rear spanwise extending spar, a series of chordwise wing ribs interconnecting the two spars and stiffened upper and lower wing skins extended between front and rear spars over the ribs to form upper and lower aerodynamic wing profiles respectively are well known. Such wings will normally accommodate at least a fixed leading edge structure forward of the front spar and a series of movable flight control surfaces such as flaps and ailerons at the trailing edge, to the rear of the rear spar.

The current method of manufacture of such a wing, which is entirely fabricated from metal, is to fabricate front and rear spar assemblies by hand which may include machining each spar from a solid billet or fabricating same from upper and lower boom sections and an interconnecting web, and then to attach riblets to the forward edge of the front spar and affix attachments for trailing edge control surfaces to the rear spar. The front and rear spar assemblies are then placed in a single jig in accurately spaced-apart relationship. Wing ribs are then manually fitted into position and secured between the spars with their positioning controlled by jigs during fitting. Aerodynamically profiled upper and lower wing skin panels are then offered up to the resulting sub-assembly to check fit. The panels on one side are then temporarily attached in position whilst those on the other side are removed to allow permanent attachment of the panels on the one side. Permanent attachment is carried out by manually drilling thousands of holes through the wing skin panels into feet of the ribs and into

the spars. These holes are then countersunk, cold worked, reamed to final size, checked for quality, sealant is injected into the countersink and a fastener is secured in the hole from both sides of the skin panel and fastened to the correct torque. Once the first set of skin panels has been attached the panels on the other side of the wing must be attached with the panels of the first side in position although hole drilling will have been carried out with the panels of the first side removed. Fastener attachment on the inside of the second set of wing panels must be carried out manually within the confines of the wing and is extremely labour intensive. Access within the wing for fastener fitting is obtained by a series of cut outs extending along the wing through one or more of the skin panels. These cut outs are subsequently closed by doors similar in style to manhole covers.

The above method is time consuming, labour intensive and the reliance upon human skills can lead to a significant proportion of fasteners failing to meet quality control standards. Exacting quality control checking is therefore necessary and remedial work can in addition be extremely time consuming to correct faults.

It is an object of the invention to provide an improved method of manufacture of an aircraft wing.

According to one aspect of the invention there is provided a method of manufacturing an aircraft wing having components comprising at least a front spar, a rear spar, wing ribs and stiffened upper and lower aerodynamic profile-defining skin panels, the method including the steps of forming a first sub-assembly including the front spar, front wing rib portions and front upper and lower skin panels, forming a second sub-assembly including the rear spar, rear wing rib portions and rear upper and lower skin panels and mating together front and rear

wing rib portions and upper and lower skin panels respectively of the first and second sub-assemblies to form the wing.

This method of assembly enables considerably enhanced access within the wing structure during assembly for the purpose of attaching fasteners.

Attachment of at least some fasteners is preferably carried out by a robot at least one end effector of which may be positionable in use within each said sub-assembly.

A method of assembly of considerably greater speed and potentially requiring less remedial work to fastenings is thus provided.

The skins panels may be fitted to each sub-assembly to create, upon joining the sub-assemblies together, substantially the entire profile surface of one of the upper and lower profiles of the wing and may leave exposed on the other profile only an area in the region of the join whereby to allow access into the wing to join the sub-assemblies together and secure the joining of said panels forming the aforesaid entire profile surface.

By this means not only fabrication of each sub-assembly but the joining together of the sub-assemblies maybe carried out robotically, access within the wing for joining the two sub-assemblies being provided through the exposed area in the said other profile of the wing.

The said other wing profile surface is preferably created by attaching front and rear spanwise extending skin panels to front and rear sub-assemblies respectively and by attaching a central spanwise extending skin panel to close the joint region of the wing.

The method desirably includes building the first and second sub-assemblies to positional data which includes a common datum corresponding to the joint between the two sub-assemblies.

The method preferably includes measuring the said positional data of each sub-assembly, comparing same with centrally stored design data for the wing and positionally adjusting the sub-assemblies by automatic means until correspondence with the design data is achieved.

Preferably the measuring and adjusting is carried out using remote sensing equipment such as photogeometry or laser position sensing equipment linked to a central design data store for the wing and servo operated positional adjustment means.

More preferably component positioning for manufacture of each sub-assembly is carried out by robot.

The method may include forming at least one of the first and second sub-assemblies with a second spar adapted to lie at the join of the sub-assemblies centrally of the wing. For large wings, where a central spar is used, the method may include fitting a slave spar to locate unsupported ends of the wing ribs to the other of the front and rear sub-assemblies pending joining together thereof.

The first and second sub-assemblies may each be supported on supports which carry the sub-assemblies in parallel through manufacturing stations which are preferably robotically

operated until the sub-assemblies are ready for joining, whereupon they are joined together upon a single carrier.

Each sub-assembly is desirably oriented such that build is carried out upwardly from each of the front and rear spars.

According to a second aspect of the invention there is provided a wing manufactured according to the method of the first aspect of the invention.

The invention will now be described by way of example with reference to the accompanying drawings in which:-

**Figure 1** shows a jig and wing under construction viewed from one side according to the prior art.

**Figure 2** is a bottom plan view of basic wing components of a wing manufactured according to the invention,

**Figure 3** is an isometric view showing robotic construction of a wing sub-assembly,

**Figure 4** is another isometric view showing sub-assembly robotic construction at a further advanced stage,

**Figure 5** is an end view of sub-assembly construction at a similar stage to that shown in Figure 4,

**Figure 6** is an isometric view of a wing assembly line,

**Figure 7a** is a section through a wing rear sub-assembly for manufacture according to the invention depicting the offering up of skin panels to the sub-assembly,

**Figure 7b** is a section through a wing front sub-assembly at the same stage of manufacture as shown in Figure 7a,

**Figure 8a** shows the sub-assembly of Figure 7a showing skin fastening and offering up of centre spar to the sub-assembly,

**Figure 8b** shows the sub-assembly of Figure 7b at the stage shown in Figure 8a,

**Figure 9a** shows the sub-assembly of Figure 7a during centre spar fastening,

**Figure 9b** shows the sub-assembly of Figure 7b idle during centre spar fastening to the sub-assembly of Figure 9a,

**Figure 10** is a section through the sub-assemblies of Figures 9a and 9b during offering up for joining together,

**Figure 11** shows the sub-assemblies joined together for fastening of ribs and upper skin joint,

**Figure 12** shows the fitting into place of a central lower skin panel covering the area of the wing joint,

**Figure 13** is a side schematic view of a pair of robot end effectors.

Referring to Figure 1, a wing assembly 1 is shown located in a single box jig 2 in which substantially the whole assembly process of each wing is carried out. Front and rear spars 3, 4 are precisely spaced from one another in the jig 2, ribs (not shown) are then slotted into position between the spars and stiffened skin panels 5, 6, 7, 8 and their equivalent on the other side of the wing are placed into position over the ribs. Fastener holes for one side of the wing are then drilled and the panels are temporarily attached in position. Fastener holes for the opposite side of the wing are then drilled, the panels from the first side are removed and the panels on the opposite side are then permanently attached, all by hand. The skin panels on

the first side are then fitted and permanently secured in place with the skin panel 8 being fitted last to allow access inside the wing for fitters to attach panels 7 and 8.

The limitations of this method of manufacture will be apparent to those skilled in the art who will note particularly the necessity for repetition of skin fitting and the limitations of access imposed by the one piece wing construction within a single jig.

Figure 2 shows basic wing components for manufacture according to the invention. An outer wing 10 may be required for large wings and its manufacture is not the subject of this invention. Figure 2 may be viewed in conjunction with Figures 4, 5 and 11. A forward or front sub-assembly 11 and a rear sub-assembly 12 are built up separately by robot on a flow line as shown in Figure 6 and a central skin panel 13 is fitted, as shown in Figure 11, at the end of the assembly process all of which has been enabled to be carried out by robot.

Early manufacture of each sub-assembly is shown schematically in Figure 3 in which a front or rear spar 14 is shown supported on a fixture 15. Two upright supports 16, 17 carry a centre spar 47 in a raised position. All wing ribs, exemplified by the rib 18 shown, are then robotically fitted into position on the spar 14 by robot 19. The centre spar is then lowered into position to contact the ribs by the supports 16, 17 automatically. The positions of all the components are then checked by photogeometry equipment 24, 25 and the positions of components adjusted automatically by the supports 16, 17 or the robot 19 until positional data supplied by the photogeometry equipment 24, 25 corresponds with that stored in a central data bank for the wing. Automated fastening is then carried out, either by the robot 19 or by another robot having suitable end effectors for carrying out drilling checking and fastening operations.

Referring to Figures 7a and 7b, skin panels 20, 21, 22, 23 are now offered up by robot to front sub-assembly 11 and rear sub-assembly 12. The front sub-assembly comprises a leading edge or front spar 26, a series of riblets 27 extending forward thereof, a series of ribs 30 extending rearwardly thereof and skin panels 22, 23 and 28. The rear sub-assembly 12 comprises a rear spar assembly 29, a series of ribs 31 and skin panels 20, 21. Referring to Figure 5 it will be seen that skin stops 32 are provided on the fixture 15 to assist in locating each skin panel. The skin panels are then held firmly in position whilst robot end effectors 33, 34 clamp, drill and countersink, cold work and ream each hole to final size, check hole quality, inject sealant into the countersink and place and attach a two-piece fastener at each location. End effectors suitable for such use are shown schematically in Figure 13 in which end effector 33 includes a pair of normality sensors 35, a drill spindle with servo motor 36, a sleeveless cold-working tool 37, a shaver/reamer with servo motor 38, a bolt feeder and driver 39, a sealant injector 40 and an electro-magnetic riveter 41. End effector 34 carries a riveting die 42, a fastener collar swaging tool 43 or alternatively a collar swaging die for two-piece fastener installation and also carries provision for fitting of a drill head (not shown). A stringer tracer 44 assists in location of the robot against the work piece.

Following attachment of the skin panels 20, 21, 22, 23 to the sub-assemblies 11, 12, as shown in Figures 5, 8a and 8b, a centre spar 47 is fitted to the rear sub-assembly, also by robot. Figure 6c also shows simultaneous fitting of the skin panels to spar sub-assemblies in parallel with each other.

Figures 10, 11 and 12 show joining of the two sub-assemblies 11, 12. The completed wing 48 is also shown being worked on at a single station in Figure 6d. It will be seen from

these figures that the sub-assemblies 11, 12 have now been turned on their side to effect the joining process.

Referring to Figure 10, it will be seen that the wing skin panel 23 does not extend to the end of the sub-assembly 12 and that the skin panel 20 has an overhang 49 to cover uncovered portion 50 of the front sub-assembly 11. Skin panels 21 and 22 both leave areas 51, 52 uncovered on the sub-assemblies. The sub-assemblies 11, 12 are now manipulated by robot into position as shown in Figure 11 meeting at a common central datum 53 and a robot having end effectors of the type discribed now carries out joining of the sub-assemblies 11, 12, one of the end effectors being inserted through the uncovered areas 51, 52 into the wing cavity to co-operate with another on the outside of the wing to attach the overhang 49 of the skin panel 20 to the front sub-assembly 11. A pair of end effectors will be inserted into the wing cavity to join up ribs and the centre spar. During this processing accurate positioning of the sub-assemblies with respect to one another is monitored by the photogeometry equipment and the positions of the sub-assemblies are adjusted as required prior to fastening taking place.

Once the two sub-assemblies 11, 12 have been joined together, as shown in Figure 11, the centre skin panel 13 is attached in position, as shown in Figure 12. This may be carried out robotically or manually. If by robot then access within the wing cavity may be obtained through cut outs 54 in the central skin panel 13. Door covers (not shown) for the cut outs 54 may be attached as required.

It will be appreciated that installation and assembly of all wing systems has not been described herein. This again is considerably eased by the method of assembly described and considerable time savings may be expected.

The present methods of aircraft manufacture on different sites and sometimes by different companies within a manufacturing group can require wings to be transported from one site to another. With the proposed advent of very large aircraft, transport of such wings could be rendered almost impossible. The method of manufacture according to the invention however allows manufacture of wing sub-assemblies of the type described which are considerably more manageable in size and which could enable such wing transportation to take place for very large wings.

From the above it will be understood that the separate flow lines shown in Figure 6 could in fact be located at different manufacturing sites, the completed sub-assemblies being brought together at a single site for final wing assembly. The handling of very large wing sections can therefore be avoided until late in the manufacturing process as well as providing significantly enhanced access to the wing interior for manufacture thereof and fitting of systems into the wing.

## CLAIMS

1. A method of manufacturing an aircraft wing having components comprising at least a front spar, a rear spar, wing ribs and stiffened upper and lower aerodynamic profile-defining skin panels, the method including the steps of forming a first sub-assembly including the front spar, front wing rib portions and front upper and lower skin panels, forming a second sub-assembly including the rear spar, rear wing rib portions and rear upper and lower skin panels and mating together front and rear wing rib portions and upper and lower skin panels respectively of the first and second sub-assemblies to form the wing.

2. A method as in claim 1 in which attachment of at least some fasteners is carried out by a robot at least one end effector of which is positionable in use within each said sub-assembly.

3. A method as in claim 1 or 2 in which the skin panels are fitted to each sub-assembly to create, upon joining the sub-assemblies together, substantially the entire profile surface of one of the upper and lower profiles of the wing and to leave exposed on the other profile only an area in the region of the join whereby to allow access into the wing to join the sub-assemblies together and secure the joining of said panels forming the aforesaid entire profile surface.

4. A method as in claim 3 in which the said other wing profile surface is created by attaching front and rear spanwise extending skin panels to front and rear sub-assemblies respectively and by attaching a central spanwise extending skin panel to close the joint region of the wing.

5. A method as in any preceding claim including building the first and second sub-assemblies to positional data which includes a common datum corresponding to the joint between the two sub-assemblies.

6. A method as in claim 5 including measuring the said positional data of each sub-assembly, comparing same with centrally stored design data for the wing and positionally adjusting the sub-assemblies by automatic means until correspondence with the design data is achieved.

7. A method as in claim 6 in which the said measuring and adjusting is carried out using remote sensing equipment linked to a central design data store for the wing and servo operated positional adjustment means.

8. A method as in any preceding claim in which component positioning for manufacture of each sub-assembly is carried out by robot.

9. A method as in any preceding claim including forming at least one of the first and second sub-assemblies with a second spar adapted to lie at the join of the sub-assemblies centrally of the wing.

10. A method as in claim 8 or 9 when dependent upon claim 8, in which the first and second sub-assemblies are each supported on suports which carry the sub-assemblies in parallel through manufacturing stations until the sub-assemblies are ready for joining whereupon they are joined together upon a single carrier.

11. An aircraft wing manufactured according to the method of claim 1.

12 A method of manufacturing an aircraft wing substantially as herein described.

13. An aircraft wing substantially as herein described with reference to the accompanying drawings.

**Patents Act 1977**
**Examiner's report to the Comptroller under Section 17 (The Search Report)** 14

**Application number**
GB 9306859.1

**Relevant Technical fields**

(i) UK Cl (Edition L) B7W-W44, WWF, WWG, WHBM

(ii) Int Cl (Edition 5) B64C - 3/00, 3/18
B64F - 5/00

**Search Examiner**
B F BAXTER

**Databases** (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

**Date of Search**
9 JUNE 1993

Documents considered relevant following a search in respect of claims 1 TO 13

| Category (see over) | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| | NONE | |

SF2(p) JL - doc99\fil000226

| Category | Identity of document and relevant passages | Relevant to claim(s) |
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